UCRL-92759
PREPRINT

HYDROSTATIC EXTRUSION OF AMORPHOUS $Fe_{82}B_{12}Si_{6}$ AND $U_{70}Cr_{30}$

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This paper was prepared for submittal to the 10th AIRAPT International High Pressure Conference, Amsterdam, The Netherlands, July 8-11, 1985

June 25, 1985

Lawrence Livermore National Laboratory

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HYDROSTATIC EXTRUSION OF AMORPHOUS $Fe_{82}B_{12}Si_6$ and $U_{70}Cr_{30}$*

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ABSTRACT

An investigation of the feasibility of forming dense cylinders from amorphous $Fe_{82}B_{12}Si_6$ and $U_{70}Cr_{30}$ platelets using a combination of die compaction and hydrostatic extrusion is described. Densities of up to 84% and 87% of theoretical were realized in one pass using an extrusion ratio of 1.6 for the iron and uranium alloys, respectively. Equations are presented for consolidation and extrusion parameters.

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*Work performed under the auspices of the U.S. Department of Energy by the Lawrence Livermore National Laboratory under Contract W-7405-Eng-48.

1. INTRODUCTION

Metal particles may be consolidated by hot pressing. However, this process is not suitable for many melt spun flake amorphous materials, because they may become crystalline when heated. Metal particles also may be consolidated by combining cold die compaction [1] with hydrostatic extrusion [2-5]. Since brittle materials flow in a ductile fashion in hydrostatic extrusion, it was felt that the extrusions would produce dense cylinders from brittle $Fe_{82}B_{12}Si_6$ and $U_{70}Cr_{30}$ platelets produced from rapidly quenched melts.

2. EXPERIMENTAL PROCEDURE

Work was divided into three steps:
(a) preparation of the amorphous platelets,
(b) fabrication of green preforms, and
(c) extrusion of billets housing the preforms.
Platelets were prepared using a stream of molten metal ejected from an orifice onto a spinning cold disk [6]. The resulting particle sizes were 400-2200 μm for the iron alloy and 70-1045 μm for the uranium

alloy. The iron alloy was further reduced to 50-500 μm by grinding under liquid N_2 using WC balls. Indentation hardness values were 1200 kg/mm^2 V_H for the iron alloy and 460 kg/mm^2 V_H for the uranium alloy.

Green preforms were made in lead-foil-lined WC dies. Relationships of Heckel [7] and Konopicky [8] were used for the die consolidation parameters. Preforms were put into hollow billets made of 304 and 316 stainless steels, 250 maraging steel, and nickel to prevent fluid intrusion (Fig. 1).

For fluid extrusion work we used sheaths with R_i/R_o of 0.7-0.8, wall thickness of ~0.2 cm, and 30° included die angle cone. Sheaths were coated with 1.2 mils lead for lubrication. Dies and anvils were made of Vascomax 350 steel (R_c of 59-60). Extrusion fluid was 75 vol% ethylene glycol - 25 vol% glycerin. Extrusion speed was 1.2 cm/min. A Harwood Engineering Co. fluid extrusion unit was used in the work. It is capable of 30 katm in the billet chamber and 2 katm in the back pressure side.

3. RESULTS AND DISCUSSION

The feasibility of producing cylinders from brittle amorphous platelets using die compacted preforms and hydrostatic extrusion was established. Table I shows typical data [9].

Equations for die compaction (Figs. 2 and 3) were determined as:

$$Fe_{82}B_{12}Si_{6}:\ \ln\left(\frac{1}{1-D}\right) = 0.0368\ P_{kbar} + 0.357$$

$$U_{70}Cr_{30}:\ \ln\left(\frac{1}{1-D}\right) = 0.03195\ P_{kbar} + 1.2\ ,$$

where D is specific density compact/compact having no voids. The differential pressure required to extrude vs ln R (R = initial area/final area) is shown in Fig. 4. Back pressure is 135 atm. Pressure equations are:

$$Fe_{82}B_{12}Si_{6}:\ P_{katm} = 9.28\ \ln R + 3.6$$

$$U_{70}Cr_{30}:\ P_{katm} = 9.74\ \ln R + 0.6\ .$$

Austenitic steels became martensitic and R_b increased from 78 to 90 during extrusion. A cursory run with nickel sheathing proved nickel to be superior because it was fissure-free and reusable for several reductions.

Table I. Densities obtained in extrusion of $Fe_{82}B_{12}Si_6$ and $U_{70}Cr_{30}$ alloys (one pass, 30° die).

Billet diam/wall thickness (cm)	Packing density in sheath (% theor)*	Extrusion ratio, R (A_0/A_f)	Extrusion density (% theor)
$Fe_{82}B_{12}Si_6$:			
1.587/0.178	69	1.6	83.6
1.587/0.178	66	1.6	84
1.862/0.198	62.7	2.06	74
$U_{70}Cr_{30}$:			
1.882/0.208	81	2.1	87.6
1.587/0.178	79.7	1.6	86.9

* Note that overall density is decreased because of uncompacted platelets used to fill voids.

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FIGURE CAPTIONS:

Fig. 1. Schematic of billet.

Fig. 2. Density in compressed cylinders of $Fe_{82}B_{12}Si_6$ vs die pressure.

Fig. 3. Density in compressed cylinders of $U_{70}Cr_{30}$ vs die pressure.

Fig. 4. Variation of extrusion pressure with extrusion ratio for $Fe_{82}B_{12}Si_6$ and for $U_{70}Cr_{30}$ (single-pass extrusion).

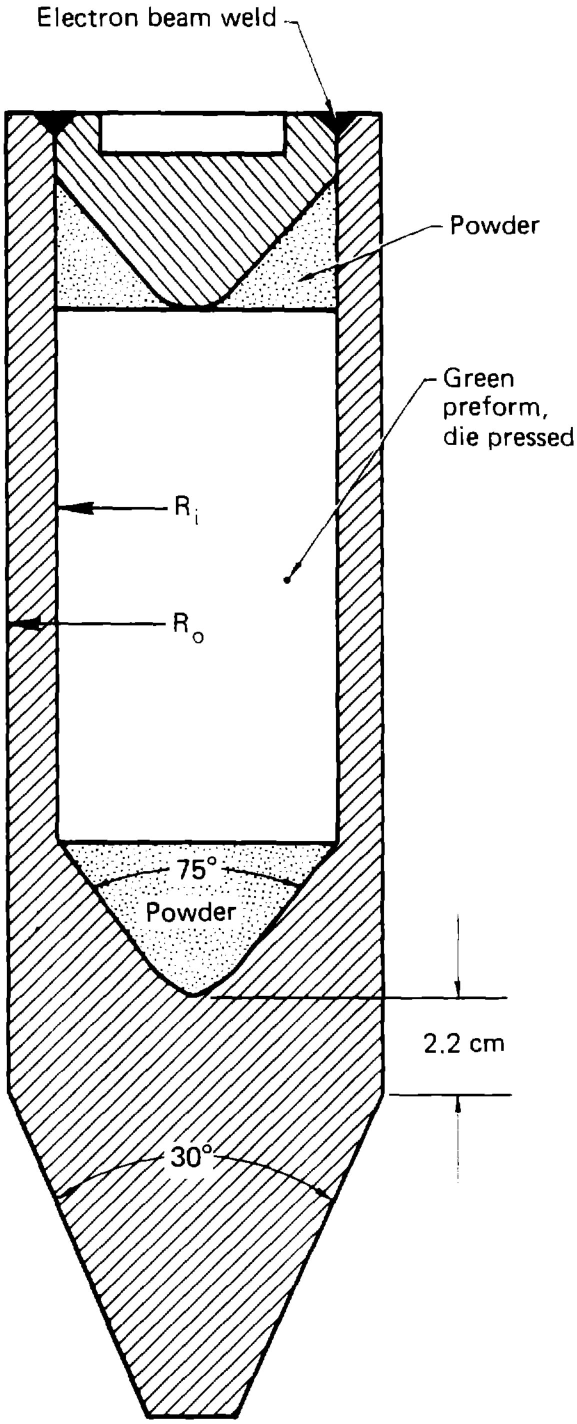

Electron beam weld
Powder
Green
preform,
die pressed
R_i
R_o
75°
Powder
2.2 cm
30°

Fig. 1

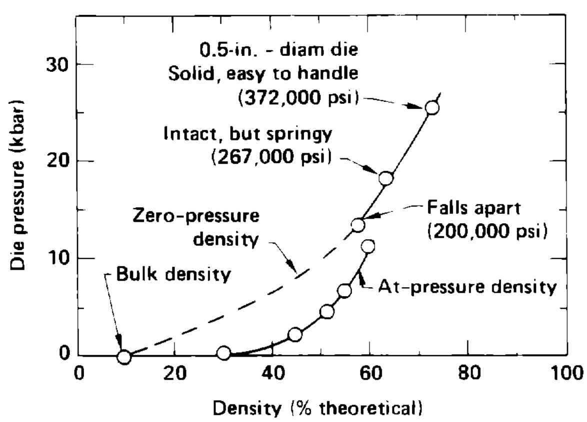
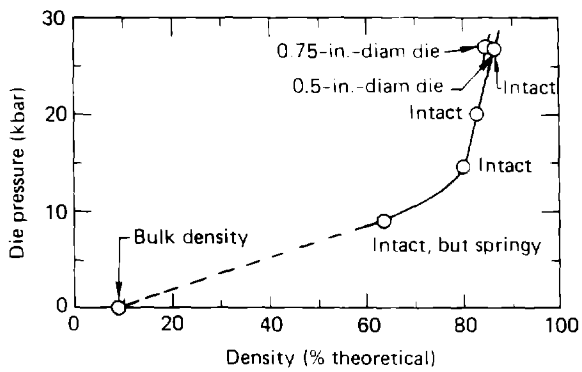
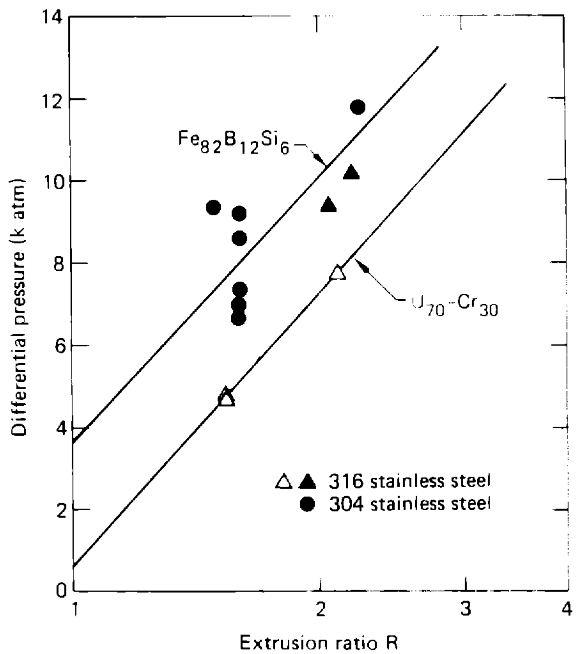

0.5-in. - diam die
Solid, easy to handle
(372,000 psi)
Intact, but springy
(267,000 psi)
Falls apart
(200,000 psi)
Zero-pressure
density
Bulk density
At-pressure density
Die pressure (kbar)
Density (% theoretical)
0
10
20
30
0
20
40
60
80
100

Fig. 2



30
20
10
0
0
20
40
60
80
100
Die pressure (kbar)
Density (% theoretical)
0.75-in.-diam die
0.5-in.-diam die
Intact
Intact
Intact
Intact, but springy
Bulk density

Fig. 3



Fe82B12Si6
U70-Cr30
316 stainless steel
304 stainless steel
Differential pressure (k atm)
Extrusion ratio R
0
2
4
6
8
10
12
14
1
2
3
4

Fig. 4